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HANDY METHODS

OF

GEODETIC ASTRONOMY

FOR

LAND SURVEYORS.

By T. GRAHAM GRIBBLE, M.Inst.C.E.

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"Preliminary Survey and Estimates," "Diurnal Atmospheric Variation in the Tropics, and Surveying with the Aneroid," and other Scientific Publications.

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USEFUL RULES.

To find the Mean Time of any Star's Culmination at *any* Meridian.

RULE 1. To the Mean Time at 0 hours Sidereal Time in the Ephemeris on the previous day, or the given day, add the Star's Right Ascension reduced to Mean Time by Table p. 79 Whitaker.

(If the two quantities make more than 24 hours take the previous day, if less, take the given day.)

RULE 2. From the Star's Right Ascension, increased if necessary by 24 hours, deduct the Sidereal Time at Mean Noon in the Ephemeris, the result will be a Sidereal interval, which, reduced to Mean Time, will be the answer.

When the Meridian is not the same as Greenwich, the Mean Time, Apparent Time, or Sidereal Time, have all to be corrected for the difference of Longitude, expressed in time.

HANDY METHODS

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GEODETIC ASTRONOMY

FOR

LAND SURVEYORS.

Probably some pioneer Engineers and Surveyors have not fully realised how complete the information contained in "Whitaker's Almanack" is for the elementary Geodetic Astronomy which they need. Bulky works of reference are better left behind, where possible. With a "Whitaker's Almanack," a book of mathematical tables, and a 20-inch slide-rule, the Surveyor can utilise his ordinary 6-inch transit-theodolite, or even one of less size, to determine his geographical position with considerable accuracy.

Philip's cardboard "Planispheres," published for either Hemisphere, are an inexpensive and most useful addition.

The particular feature of this pamphlet is, however, to show how, by means of some rapidly made diagrams, the stars available at time and place can be at once identified, and the observation facilitated.

"WHITAKER'S ALMANACK."

The information most useful to Surveyors which this comprehensive and inexpensive work contains is as follows:—

1. THE EPHEMERIS. The Sun's place and that of the Pole Star are given, the former by daily positions in Right Ascension and Declination, with the variations per hour; the latter by similar figures four times in each month. In all Latitudes the Sun is the most generally useful object for the Surveyor, and next to it, in Northern Latitudes, comes the Pole Star. In both cases, the "apparent" places of these objects are given in the Ephemeris, that is to say, the places in which they would be seen in the telescope if there were no refraction.

The Pagination of Whitaker is that of the Issue of 1921

2. THE LIST OF PRINCIPAL FIXED STARS. In this list the " mean " places of 100 fundamental stars, visible at Greenwich, are given, also of 14 stars visible in the Southern Hemisphere. It will be noticed that the place of Polaris on 1st January, given in this list, does not precisely agree with that for the same date in the Ephemeris. The difference is that between the " mean " and the " apparent " place. The so-called " fixed stars " have in reality many kinds of motion, real or apparent.

(A) The " Proper " motion is explained on p. 84 of the " Almanack."

(B) PRECESSION, the annual amount of which in each case is stated in the list, is the constant though extremely slow motion of the " Pole of the Equinoctial," or vanishing point of the Earth's axis among the stars. It is analogous to the conical gyration of the spindle point of a top.

(C) NUTATION is an undulatory modification of the above conical motion, by which a closed curve is described in about nineteen years.

(D) ABERRATION is an optical displacement due to the comparative velocities of light and of the Earth itself. The effect is in this respect different from that of Precession and Nutation, whereas these do not affect the *relative* positions of the stars among themselves, Aberration produces an apparent displacement of the objects one among the other.

This cursory explanation merely serves to explain the apparent discrepancy of the Ephemeris as regards the Pole Star, of which the mean and apparent places are given, and also to note the fact that the correction for Precession up to date is not a complete one. The " mean " places of the list are sufficiently approximate for the Surveyor's purpose, especially if they are brought up to the date of the observation by applying the appropriate fraction of the annual Precession. The difference between the place thus found and the precise apparent place can be seen in the case of the 24 stars whose apparent places are given in " Whitaker," p. 83. No transit theodolite, to be sufficiently portable, is graduated more closely than 20 seconds, and this degree of precision can only be attained in the final result by repeated observations. The difference between the mean and apparent places seldom exceeds 20 seconds.

The value of the fixed stars, other than Polaris, as objects, increases as we get nearer to the Equator, where the Sun ceases to be observable at culmination, and where Polaris is too near the horizon.

The correction for refraction is not given in " Whitaker," but is in most mathematical tables. An approximate curve is given in the diagrams. It is always a deduction from the observed Altitude.

3. The Tables on pp. 78, 79 for determining the Latitude from observations of the Altitude of the Pole Star out of the Meridian, are said in the text books to be used by Navigators. They require extremely careful calculation to obtain correct results. To the Surveyor, a culmination of a fixed star is much handier and altogether preferable.

4. The Tables on pp. 80, 81 of eclipses of Jupiter's Satellites and occultations of fixed stars by the Moon, are both of possible utility to Surveyors for the independent determination of the Longitude. Their practical value is, however, lessened by the increased facility of obtaining the Greenwich Mean Time by wireless telegraph.

5. The Table on p. 76 for finding the times of Sunrise and Sunset in any place and at any date, which is also in most books of mathematical tables, is useful, taken in connection with the Ephemeris, for ascertaining what stars will be visible on the night in question.

6. The Table on p. 79 for reducing Sidereal Time to Mean Time and *vice versâ*, is handily arranged, and is needed in reducing the Hour-Angle to time and in finding the time of culmination. Some useful information is given on p. 101 as to Terrestrial magnetism. A table of Mean Magnetic Declination at all principal outposts of the British Empire would be a useful addition.

THE TRANSIT-THEODOLITE.

This instrument should be provided with a diagonal eye-piece. Otherwise the ordinary theodolite will not conveniently take vertical angles of more than 55°. It is supposed, in this pamphlet, that the observer is thus limited. If the instrument is not made with a perforated axis for purposes of illuminating the diaphragm, an electric torch, held by an assistant close to the object-glass, forms a fairly good substitute. The field of a six-inch theodolite, with ordinary eye-piece, is about two degrees. When fitted with an extra powerful eye-piece, the field is reduced to about one degree. The apparent movement of stars near the Pole is very slow, and they are easily found. Under certain conditions of Latitude and Declination, stars will appear to pass across the field in two or three minutes, and are, therefore, easily missed by an inexperienced observer, unless he knows their approximate place, so as to bring them within the field.

THE COMPASS.

Theodolites with a complete compass-dial are practically obsolete. A "trough-needle" is all that is supplied. The vernier plate being clamped at 360°, the needle is brought to the centre of its run by the external axis. The telescope then points to the magnetic North of the place of observation. Clamping then the external axis and releasing the vernier plate, some fiducial point such as a church spire or lightning conductor is chosen and its bearing on the vernier plate (which of course is its magnetic bearing) booked for reference. The observation for determining the astronomical North is then taken by an Azimuth of the Sun or Star, calculated by equations to be presently given. The magnetic bearing of the celestial body at the time of observation differs from the bearing found from the Azimuth by the amount of magnetic Declination. The astronomical bearing of the fiducial point is then registered.

The following rule will be found useful, especially when the magnetic Declination is small. Supposing that the instrument reads, as is now almost universal, from 0 to 360° on the vernier plate as turned from N. to E., the rule is as follows :—

When the magnetic Declination is West, the magnetic bearing is greater than the astronomical bearing and *vice versâ*.

For instance, in a place where the magnetic Declination was 14° West and the magnetic bearing of a church spire was 246°, taken either by the theodolite in the manner just described, or by a prismatic compass, the astronomical bearing would be 232°. In the case of a miner's dial or prismatic compass reading in the four quarter-circles, in the above case, the astronomical North will be read when the dial records 14° N.E. and the astronomical South when it records 14° S.W. After the determination of the true Meridian, the needle is of no further use, than to book from time to time the variation in the magnetic Declination at the base station.

THE SLIDE-RULE.

The ordinary 10-inch Slide-Rule is not of very much service for the calculations herein considered. The 20-inch size, with a magnifying cursor, is of sufficient accuracy for a large portion of the work. The trigonometrical functions being booked as decimal fractions, the multiplication or division of them can be performed with increased accuracy on the lower and more open scale of the rule.

PLANISPHERES.

Philips' Cardboard Planispheres, published for both Northern and Southern Hemispheres, possess almost the utility of a celestial globe, together with the advantage of extreme portability. They are also quite inexpensive. The former is constructed for the Latitude of Greenwich, the latter for Latitude 35° South or (roughly speaking) of Cape Town or Sydney, N.S.W. They are of quite practical application, however, to the whole of the two Hemispheres. They show the general position of the principal stars visible for every hour of the year. Sidereal Time is at once rendered intelligible by them to any one. They cannot, of course, convey the idea of Altitude with anything like correctness.

DIAGRAMS.

When selecting the celestial bodies for observation, the Surveyor will find it of considerable assistance, if in a Latitude with which he is not familiar, and possibly himself not much of an astronomer, to be able rapidly to classify the stars available at time and place, from the list given in Whitaker's Almanack. Obviously not all the visible, nor even all the listed and visible stars are suitable or convenient.

In almost all parts of the world, the Latitude and Longitude can be *roughly* ascertained from a map. Having then, even quite approximately, the Latitude of the place, a diagram can be made in a few minutes,

which will show the *Altitude* at which any listed visible star will culminate, with sufficient accuracy to *identify* it when crossing the Meridian. With regard to the further observations for fixing the Meridian and Longitude precisely, curves can be added to the diagram to show the *Azimuths* and *Hour-Angles* at the time of observation, by means of calculations of such extreme simplicity that they can be performed, where no mathematical tables are at hand, by means of the Slide-Rule, with in most cases as great an accuracy as that of the graduation of the theodolite.

The Altitudes at which culminations take place in any Latitude are shown by straight lines. The curves show the Altitude, Azimuth and Hour-Angle of a celestial body when in one of the three following positions :—

(A) At Eastern or Western Elongation.

(B) When the Azimuth is 90°.

(C) When the Hour-Angle is 90°.

The observation at Elongation has the advantage of being defined by the movement of the object for a short time vertically up or down the field.

These diagrams serve :—

(1) To define precisely which celestial objects are the most suitable for observation.

(2) To locate these objects sufficiently to permit the telescope to be directed to where they will be

Not only is it sometimes difficult for an observer who is not a professional astronomer, to be sure of the star he wants, but also, in twilight and when the night is not very clear, the time spent in searching for the object, frequently allows clouds to obscure it. If, however, the telescope is directed by the help of the diagram sufficiently near the spot to bring the object within the field, it can sometimes be discerned through the telescope when the haze has rendered it invisible to the naked eye, or in twilight. It also makes the identity certain.

The three diagrams, Figs. 2, 3 & 4, are merely illustrative of the simplicity and rapidity with which similar diagrams can be made for any Latitude. All the Equations are soluble by the 20-inch Slide-Rule, except Nos. (12) and (13).

In the following description, the upper alternative designation refers to the Northern, the lower to the Southern Hemisphere. The argument is the Declination which is read in degrees on the horizontal scales. The corresponding Altitude, Azimuth or Hour-Angle on the vertical scales. In the curve of refraction, the argument is the Altitude, in degrees on the vertical scale and the refraction is read in minutes on the horizontal scale.

THE CONSTRUCTION OF THE DIAGRAM.

Line A is the Meridional Altitude of the Sun or Star of $\frac{\text{Northern}}{\text{Southern}}$ Declination, when culminating $\frac{\text{Southwards.}}{\text{Northwards.}}$

(1) Altitude = Co-Latitude + Declination.

It will be noticed that this line is drawn from the Co-Latitude on the $\frac{\text{Left hand}}{\text{Right hand}}$ vertical scale to the Latitude on the upper horizontal scale. If, for instance, the theodolite will only take angles up to 55°, and we want to know whether Aldebaran can be observed at culmination in the region of Greenwich, we proceed as follows :— Turning up the Declination of Aldebaran in " Whitaker's list," p. 82, we see from the diagram that all stars whose North Declination does not exceed 16½° are within range. The Sun, moreover, we see from the " Almanack " will be observable for this purpose except in the months of May, June, and July.

Line B is the Meridional Altitude of he Sun or Star of $\frac{\text{Southern}}{\text{Northern}}$ Declination, culminating $\frac{\text{Southwards.}}{\text{Northwards.}}$

(2) Altitude = Co-Latitude — Declination.

This line is drawn from the Co-Latitude on the lower horizontal scale to the Co-Latitude on the $\frac{\text{Left hand}}{\text{Right hand}}$ vertical scale.

Curve C is the Altitude of the Sun or Star, when its Azimuth is 90° East or West of the Meridian.

$$\text{(3) Sin. Altitude} = \frac{\text{Sin. Declination} \times \text{R}}{\text{Sin. Latitude}}$$

R, in the logarithmic solution, = 10·0000000.

Curve D is the Hour-Angle, when Azimuth is as in C.

$$\text{(4) Cos. Hour-Angle} = \frac{\text{Tan. Declination} \times \text{R}}{\text{Tan. Latitude}}$$

Curve E is the Altitude of the Sun or Star, when its Hour-Angle is 90°.

$$\text{(5) Sin. Altitude} = \frac{\text{Sin. Declination} \times \text{Sin. Latitude}}{\text{R}}$$

Curve F is the Azimuth of the same, when Hour-Angle is as in E.

$$\text{(6) Cot. Azimuth} = \frac{\text{Cos. Latitude} \times \text{Tan. Declination}}{\text{R}}$$

Line G is the Meridional Altitude of a Star, when culminating $\frac{\text{Northwards}}{\text{Southwards}}$ above the Pole.

(7) Altitude = Latitude + Co-Declination.

This line is drawn from the Latitude on the $\frac{\text{Right hand}}{\text{Left hand}}$ vertical scale to the Latitude on the upper horizontal scale. In high Latitudes it applies to a limited number of circumpolar stars. Near the Equator it includes a great number of stars, not only circumpolar.

Line H is the Meridional Altitude of a Circumpolar Star, when culminating $\frac{\text{Northwards}}{\text{Southwards}}$ below the Pole.

(8) Altitude = Latitude — Co-Declination.

This line is drawn from the Co-Latitude on the lower horizontal scale to the Latitude on the $\frac{\text{Right hand}}{\text{Left hand}}$ vertical scale. In high Latitudes this class of stars, together with those in B, are the most useful for this kind of observation.

It will be noticed that when the Latitude is known, even quite roughly, from a map, the four lines A, B, G and H, can be drawn in a few minutes on section paper.

Curve I is the Altitude of a Circumpolar Star, when at Elongation.

$$\text{(9) Sin. Altitude} = \frac{\text{Sin. Latitude} \times R}{\text{Sin. Declination}}$$

Curve J is the Azimuth of Ditto.

$$\text{(10) Sin. Azimuth} = \frac{\text{Cos. Declination} \times R}{\text{Cos. Latitude}}$$

Curve K is the Hour-Angle of Ditto.

$$\text{(11) Cos. Hour-Angle} = \frac{\text{Tan. Latitude} \times R}{\text{Tan. Declination}}$$

Wherever Polaris in the Northern, or one of the stars near the Pole of the Southern Hemisphere can be seen, this observation is one of the most useful for fixing the Meridian. Equation (10) can be solved by the 20-inch Slide-Rule to the fraction of a minute of arc.

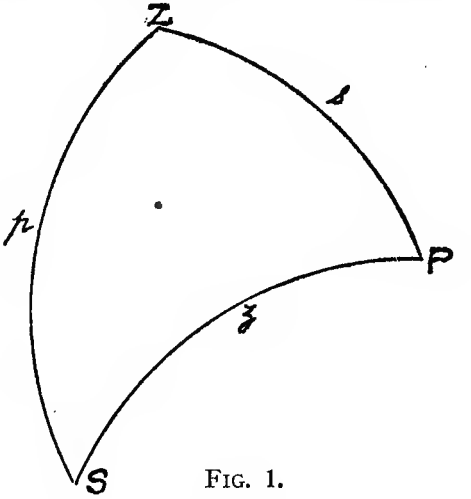


FIG. 1.

The spherical triangle, Fig. 1, requiring solution consists in all cases of the Co-Latitude s, the Co-Declination z, and the Co-Altitude p. Z being the Zenith, P the Pole and S the Sun or Star.

The angle at P is the Hour-Angle, the angle at Z is the Azimuth or its supplement. The angle at S is that between two great circles passing through the Star and the Zenith and Pole respectively. When it is a right angle the Star is at Elongation, and its position is calculated by Equations (9), (10 and (11). When Z is a right angle, the solutions are as in (3) and (4). When P is a right angle, as in (5) and (6).

At all other times of observation, the triangle is oblique, and is solved from the knowledge of the three sides.

Let $M = \frac{1}{2}(p + z + s)$, then :—

(12) $\text{Cos. } \frac{1}{2} Z = \sqrt{\frac{\text{sin. } M \times \text{sin. } (M-z)}{\text{sin. } s \times \text{sin. } p}}$ for the Azimuth ;

and

(13) $\text{Cos. } \frac{1}{2} P = \sqrt{\frac{\text{sin. } M \times \text{sin. } (M-p)}{\text{sin. } s \times \text{sin. } z}}$ for the Hour-Angle.

GREENWICH TIME.

The determination of the Longitude from the telegraphic communication of Greenwich Time is now practicable nearly all over the world. The laborious methods of Lunar distances, eclipses of Jupiter's Satellites or occultations of fixed stars by the Moon are very seldom resorted to. The former need of a couple of expensive full chronometers has given place to a single first-class stop-watch. Since 1883 the system of Standard Time by Zones has gradually been adopted in most civilised countries, all at even hours or half-hours fast or slow of Greenwich.* Recently, public attention was drawn to the establishment of the 129th Meridian from Greenwich, for boundary purposes in Australia, by wireless telegraphy, with only one intermediate station. This facility is certain to increase. The American station established in France has a range equal to half the Earth's circumference.

In order now to explain the use of the diagrams particularly, we will suppose that on the same date, October 15th, 1920, observers were locating their precise positions :—

(1) In the West of England.

(2) Near Colombo, Ceylon.

(3) Near Sydney, New South Wales.

* See Whitaker, p. 93.

THE GREENWICH DIAGRAM.

The observer, in this case, was in Somersetshire, and scaled his Latitude and Longitude from the Six-inch Ordnance Map. An ordinary Atlas would have been sufficient for the preliminary purpose. The Greenwich Diagram, although differing in basis by more than half a degree of Latitude was quite approximate enough to give the required information. Greenwich Time was obtained from the nearest railway station.

The observations to be taken were :—

(1) One for the precise determination of the Latitude, preferably by culmination of the Sun.

(2) One for fixing the Meridian, preferably by observing a star at Elongation.

(3) One for determining the Longitude by the transit of a star across the Meridian as found from (2).

On the 15th October, 1920, the Sun's Declination was 8° 30′ 42″ South. Turning to the Diagram, line B, we see that bodies of Southern Declination up to 38° can be observed at culmination. The Sun will therefore be available and at a very convenient Altitude.

Turning to the stars visible at sunset, we see from the Almanack that sunset takes place at 6 minutes past 5. We see also that at Mean Noon, the position of the starry sphere was given by 13h. 34m. 51s. Sidereal Time. In other words, a star having a Right Ascension of that amount would be on the Meridian at Mean Noon. Similarly a star of that amount plus 5h. 6m. would culminate at sunset. The Pole Star had a Right Ascension of 1h. 33m. 37s. Adding 24 hours to this and subtracting from it the Sidereal Time at Mean Noon, we have the Sidereal Time interval from Mean Noon to the culmination of the Pole Star ; 11h. 58m. 46s. The Hour-Angle of Polaris at Elongation, in form of its Sidereal Time equivalent, deducted from this Sidereal Time of culmination, will give us the Sidereal interval from Mean Noon of the Elongation, which as presently will be seen, occurs at a convenient time after sunset, and is therefore the most suitable observation for fixing the Meridian.

With regard to fixing the Longitude, referring to the Diagram, Lines A and B, we see that stars of Northern Declination up to 16½° can be observed at culmination with an instrument whose vertical range is 55°, also stars of Southern Declination up to 38°.

Of circumpolar stars culminating above the Pole we see from Line G that we can only use those whose Declination is over 86½° ; of those culminating below the Pole, we can use those whose Declination is between 38½° and 90° and includes 24 in the list. Polaris itself could be utilised for this purpose, but its apparent orbit is so small that a star culminating Southwards and fairly near the celestial equator would be preferable, provided that this took place at a period after sunset sufficient to allow for first having fixed the Meridian exactly. Turning to Whitaker's list we have α Aquilæ (Altair) culminating at a Sidereal interval from

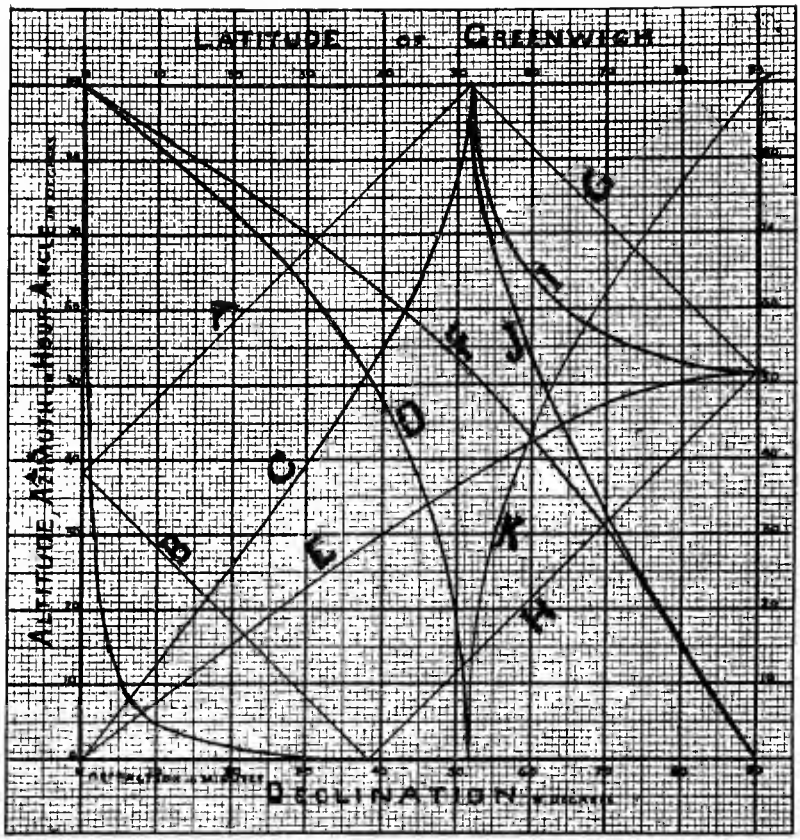


FIG 2.

LET λ = LATITUDE; δ = DECLINATION.

A. Meridional Altitude of Sun or Star of Northern Declination culminating Southwards ... (1) Alt. $= 90° - \lambda + \delta$.

B. Ditto of Southern δ ditto ditto (2) Alt. $= 90° - (\lambda + \delta)$.

C. Altitude when Azimuth $= 90°$ ... ... (3) Sin. Alt. $=$ sin. $\delta \div$ sin. λ.

D. Hour-Angle ditto ditto ... ... (4) Cos. H.-A. $=$ tan. $\delta \div$ tan. λ.

E. Altitude when Hour-Angle $= 90°$ ... ... (5) Sin. Alt. $=$ sin. $\delta \times$ sin. λ.

F. Azimuth ditto ditto ... ... (6) Cot. Azim. $=$ cos. $\lambda \times$ tan. δ

G. Meridional Altitude of Star culminating Northwards above the Pole ... ... (7) Alt. $= \lambda + 90° - \delta$.

H. Ditto when culminating below the Pole ... (8) Alt. $= \lambda - (90° - \delta)$.

I. Altitude of Circumpolar Star when at Elongation ... ... (9) Sin. Alt. $=$ sin. $\lambda \div$ sin. δ.

J. Azimuth of ditto ... ... (10) Sin. Azim. $=$ cos. $\delta \div$ cos. λ.

K. Hour-Angle of ditto ... ... (11) Cos. H.-A. $=$ tan. $\lambda \div$ tan. δ.

Mean Noon of 6h. 12m. 4s., α^2Capricorni at 6h. 38m. 49s. ; ε Pegasi 8h. 5m. 26·7s., any one of which we see from Lines A and B of the Diagram would be within range of the instrument.

1. Culmination of the Sun for Latitude.

Latitude as scaled from the Map	...	50° 57′·5 N.
Longitude as scaled from the Map	...	3° 12′·3 W.

Transposing Equ. 2 ; Alt. + $\delta = 90° - \lambda$

Observation.

Apparent Altitude ☉		30° 49′ 30″
Semi-diameter		16′ 4″
Apparent Altitude ⊕		30° 33′ 26″
Refraction	—	1′ 36″
		30° 31′ 50″
Parallax	+	8″
True Altitude ⊙		30° 31′ 58″
Declination South		8° 30′ 42″
Co-Latitude $(90° - \lambda) =$		39° 2′ 40″
Latitude $\lambda =$		50° 57′ 20″

When making this observation, the instrument was provisionally oriented by the compass, assuming a Western Magnetic Declination of 15° (See Whitaker p. 102). This assumed Meridian was referred to the bearing of a lightning conductor on a monument about two miles distant.

2. Polaris at Elongation for Meridian.

Having now ascertained the Latitude with the precision possible in the instrument, we can proceed to calculate Altitude, Azimuth and Hour-Angle of any star when at Elongation from Equations (9), (10) and (11). Using Polaris, it is sufficient for our purpose to calculate only the Azimuth exactly, and to take the other data approximately from the Diagram. We have already seen that on the date in question, the Sidereal interval from Mean Noon of Polaris culmination is 11h. 58m. 46s. From the Diagram we see that its Hour-Angle (Line K), is about $88\frac{1}{2}°$ or nearly 6 hours, which deducted from the previous figure, gives us the Sidereal interval from Mean Noon of the Elongation. From the known Latitude and the Declination of Polaris as given in the Almanack, by Equation (10) we find the Azimuth at Elongation to be 1° 46′·45. With the provisional orientation of the instrument by means of the compass, Polaris is then observed until its movement is purely vertical, and the instrumental error corrected.

3. Transit of a Star for Longitude.

Having now the true Latitude and the Meridian and the Greenwich Time, we select any most convenient star. The difference between the Greenwich Time of transit at Greenwich, and the Greenwich Time of transit at place, reduced to Sidereal Time and then to its angular equivalent, is the Longitude of the place.

Taking, for instance, ε Pegasi, which culminates at a Sidereal interval from Mean Noon on that evening of 8h. 5m. 26·7s.; reducing this by Table on p. 79, we find the Mean Time of transit at Greenwich to be 8h. 4m. 7s. The transit took place at the observation at 8h. 16m. 54s., thus 12m. 47s. *later* of Mean Time. The star, however, travels at Sidereal rate which by Table we see is 2s. faster. The angular equivalent of 12m. 49s. is 3° 12′ 15″ which is the Longitude of the place, *West*.

With these three observations, the position of the base station is completely defined. Future observations are only necessary for the regulation of the watch. This is always most readily performed by observation of the Sun's transit. When the Northern Declination is too great for observing the Sun's culmination, it can be observed out of the Meridian and the time calculated from the Hour-Angle, an example of which is here added :—

4. Correction of Watch by Solar Hour-Angle.

July 24th, 1920. Observed $\overline{\odot}$ East of Meridian.

Latitude by observation 50° 57′ 20″ Longitude 3° 12′ 15″W.

Summer Time of observation by watch set on Greenwich Time one week previously.		Altitude.	Bearing.
7h. 40m. 45s.		18° 57′ 20″	81° 20′
Greenwich Time of observation by watch ..		.. ..	6h. 40m. 45s.
Sun's Declination at Mean Noon Greenwich ..		.. ..	19° 53′·3 N
Plus 5½ hours × ′·52		.. ..	2′·7
Declination at time of observation		.. ..	19° 56′·0
Co-Declination		.. " z "—	70° 4′
Co-Latitude		.. " s "—	39° 2′·67
Apparent Altitude $\overline{\odot}$		18° 57′ 20″	
Semi-diameter		15′ 46″	
Apparent Altitude $\overline{\odot}$		18° 41′ 34″	
Refraction	—	2′ 47″	
		18° 38′ 47″	
Parallax	+	8″	
True Altitude $\overline{\odot}$		18° 38′ 55″	
Co-Altitude		.. " p "=	71° 21′·08
			2)180° 27′·75
		M =	90° 13′·87
		p —	71° 21′·08
		M—p =	18° 52′·79

Equation (13).

	Log. sin. M	9·9999965
+	Log. sin. M—p ..	9·5099776
+	Log. sec s	10·2007120
+	Log. cosec z	10·0268306
		2)19·7375167
	Log. cos. ½ P = ...	9·8687583 = 42° 20′·23
		2
	Hour-Angle P	84° 40′·46

Ditto in apparent time	5h.	38m.	42s.
Equation of time + 5½ hours × ·05s. ..			·3
Hour-Angle in Mean Time ..	5h.	38m.	42·3s.
Mean Time of Sun's culmination Greenwich	12h.	6m.	18s.
Longitude of place in time		12	49
Greenwich Time of Sun's culmination at place	12h.	19m.	7s.
Less Hour-Angle in Mean Time	5	38	42·3
Greenwich Time of observation at place	6h.	40m.	14·7s.
Greenwich Time by watch	6	40	45
Watch fast, seconds			30·3s.

The comparative length of this calculation emphasizes the preference to be given to a transit observation, where possible, whether of Sun or Star. In this case, the Sun would have been too high for observation at culmination, but the Watch might have been corrected by the very simple calculations, either of the Sun when its Hour-Angle was 90° by Equations 5 & 6, or when its Azimuth was 90° by Equations 3 & 4. In either case, the correction of the Declination to time of observation would be obtained from the diagram.

Four other stars, besides Polaris, of the "Little Bear," are listed in Whitaker; the Declination of which permits of their being observed in the Latitude of Greenwich with an instrument not furnished with a diagonal eye-piece, when these stars are at Elongation. As they differ greatly in Right Ascension from Polaris, one or other of them is practically always available when the Pole Star is not.

COLOMBO DIAGRAM.

In Colombo, as will be at once seen from the diagram, a Meridional Altitude of the Sun is out of range at all times of the year. It can be observed three hours or more from noon for determining the Meridian, Longitude or Time by Equations (12) and (13). It will also be seen that the Pole Star is too near the horizon for convenient observation. A large number of brilliant stars is, however, brought into range.

For Meridional Altitude we see from Line B that all stars of Southern Declination 28° to 83° culminating Southwards can be observed, and all stars culminating Northwards, whose Northern Declination ranges from 42° to 90°, as seen from Line G. These two lists include 35 stars of the list in "Whitaker." Among the brightest are Fomalhaut, southing at about 53° Altitude, Canopus at about 30° Altitude, α Crucis at about 20°. To the North, Vega culminates above the Pole rather high for an ordinary instrument, but is very convenient for observation at Elongation. All the chief stars of the Great Bear can be observed at culmination above the Pole at Altitudes from 35° to 50°. Capella culminates at about 50° Altitude.

Supposing, then, that on the date in question, 15th October, 1920, it was desired to determine the geographical position in the neighbourhood of Colombo, the first question, as always, being the Latitude.

In Colombo the Standard Time for India is adopted, $5\frac{1}{2}$ hours fast of Greenwich, the local mean time being actually some $10\frac{1}{2}$ minutes slow of the standard time. For the sake of simplicity, we will suppose that, after obtaining the true and exact Indian time from the most reliable source, we put the watch back $5\frac{1}{2}$ hours, and so set it on true Greenwich time.

Having roughly scaled the Latitude and Longitude from the best map available, and having approximately oriented the instrument by the compass, corrected for the assumed magnetic variation, we proceed to study the position of the stars on the night in question, from the Planisphere, if we have one, or else from the Ephemeris of the "Almanack."

The local apparent time of Sunset we find from the table on p. 76 to be about 6 p.m., and from the Ephemeris the Sun's Right Ascension to be a little more than 13 hours. At Sunset, then, stars of a little more Right Ascension than the Sun, such as η Urs. Maj. (Benetnasch) will be nearly setting. A star of about 6 hours more Right Ascension, such as β Cygni, will be nearly culminating. Stars of 12 hours more Right Ascension than the Sun, such as β Arietis, will be just rising. Polaris, which is circumpolar, will be almost at Eastern Elongation.

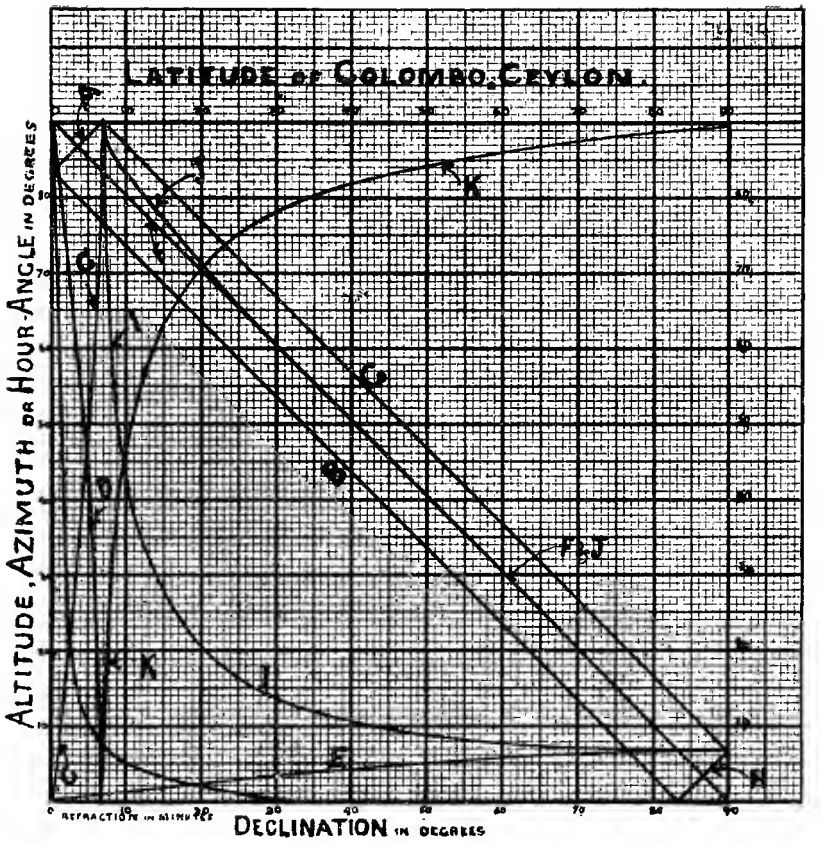


FIG. 3.

LET λ = LATITUDE; δ = DECLINATION.

A.	Meridional Altitude of Sun or Star of Northern Declination culminating Southwards ...	(1) Alt. $= 90° - \lambda + \delta$.
B.	Ditto of Southern δ ditto ditto	(2) Alt. $= 90° - (\lambda + \delta)$.
C.	Altitude when Azimuth $= 90°$	(3) Sin. Alt. $=$ sin. $\delta \div$ sin. λ.
D.	Hour-Angle ditto ditto	(4) Cos. H.-A. $=$ tan. $\delta \div$ tan. λ.
E.	Altitude when Hour-Angle $= 90°$...	(5) Sin. Alt. $=$ sin. $\delta \times$ sin. λ.
F.	Azimuth ditto ditto	(6) Cot. Azim. $=$ cos. $\lambda \times$ tan. δ.
G.	Meridional Altitude of Star culminating Northwards above the Pole	(7) Alt. $= \lambda + 90° - \delta$.
H.	Ditto when culminating below the Pole ...	(8) Alt. $= \lambda - (90° - \delta)$.
I.	Altitude of Circumpolar Star when at Elongation...	(9) Sin. Alt. $=$ sin. $\lambda \div$ sin. δ.
J.	Azimuth of ditto	(10) Sin. Azim. $=$ cos $\delta \div$ cos. λ.
K.	Hour-Angle of ditto	(11) Cos. H.-A. $=$ tan. $\lambda \div$ tan. δ.

For convenient observation at culmination, α Cygni (Deneb) might be chosen. Its difference of Right Ascension of over 7 hours shows that it will be thoroughly dark before the culmination takes place. From the diagram we see that its Altitude will then be about 52°. Directing the instrument by the assumed orientation and scaled vertical angle, the object cannot possibly be mistaken.

Supposing then the maximum Altitude to have been observed and to be ... ... 51° 53′ 0″

Deduct Refraction 44

True Altitude ... ... 51° 52′ 16″

Whence by Equation (7) Altitude = Latitude + Co-Declination.

Co-Declination (" Whitaker ") ... 45° 0′ 12″·9

Whence Latitude ... ... 6° 52′ 3″·1

Having now the Latitude, we proceed to determine the Meridian and the Longitude. For the former, the magnificent star α Lyrae (Vega) would be found a suitable object at Elongation, for a calculation of Azimuth. The Hour-Angle and Altitude can be taken with sufficient accuracy from the diagram, the only calculation being the simple one of Equation 10.

The Hour-Angle, from Curve K, we scale at $81\frac{1}{2}° = 5h.\ 26m.$

The difference of Right Ascension between Vega and the Sun on that date was about $5\frac{1}{4}$ hours. The Elongation would therefore be watched for at about half-past ten local time. The Altitude we scale from Line I at about $10\frac{3}{4}°$. The Azimuth, by Equation 10, is :—

Cos. Declination ÷ Cos. Latitude = ... N.51° 48′ 38″W.

Or on the instrument reading ... 308° 11′ 22″

Suppose, for instance, that the actual bearing taken from the provisional orientation was 307° 33′.

The error of orientation would be ... 38′ 22″E.

Correcting this error and setting the instrument on the true Meridian, we can await the transit of Polaris or α Persei. We can see from the Ephemeris and diagram that the former would culminate about midnight, and at an Altitude of about 8°, therefore very likely to be obscured. The latter star, about two hours later, but at a much more convenient Altitude. In practice, both or any other listed star would be watched for, whose culmination took place that same evening.

Supposing then that α Persei were observed, the diagram would be useful in defining it, as it is not very far from the variable star Algol.

Supposing also that the watch was set on true Greenwich time and the time by watch of the transit was ... 8h. 22m. 0s.

Right Ascension of α Persei + 24 hours ...	27h.	18m.	39s.
Sidereal time Mean Noon Greenwich ...	13	34	51
Sidereal interval at Greenwich to the culmination of α Persei	13h.	43m.	48s.
Retardation (Whitaker, p. 79)		2	15
Mean time of culmination at Greenwich ...	13h.	41m.	33s.
Mean time of culmination at place ...	8	22	08
Difference in Mean time	5h.	19m.	25s.
Acceleration (Whitaker, p. 79)			52
Sidereal interval between the culminations	5h.	20m.	17s.
= Longitude E	80°	4′	18″

AT THE EQUATOR.

LINES A AND H = O.

LINES B AND G become the diagonal of the diagram. Stars of North and South Declination culminate to the North or South and have a Meridional Altitude = 90°—δ.

CURVES C AND D. The only stars having an Azimuth = 90° are those whose Declination = O, namely, those situated on the Celestial Equator, and this Azimuth is continuous through their orbit.

CURVES E, F, I, J, K. The stars are all on the horizon when the Hour-Angle = 90°, and when at Elongation. There are no Circumpolar Stars.

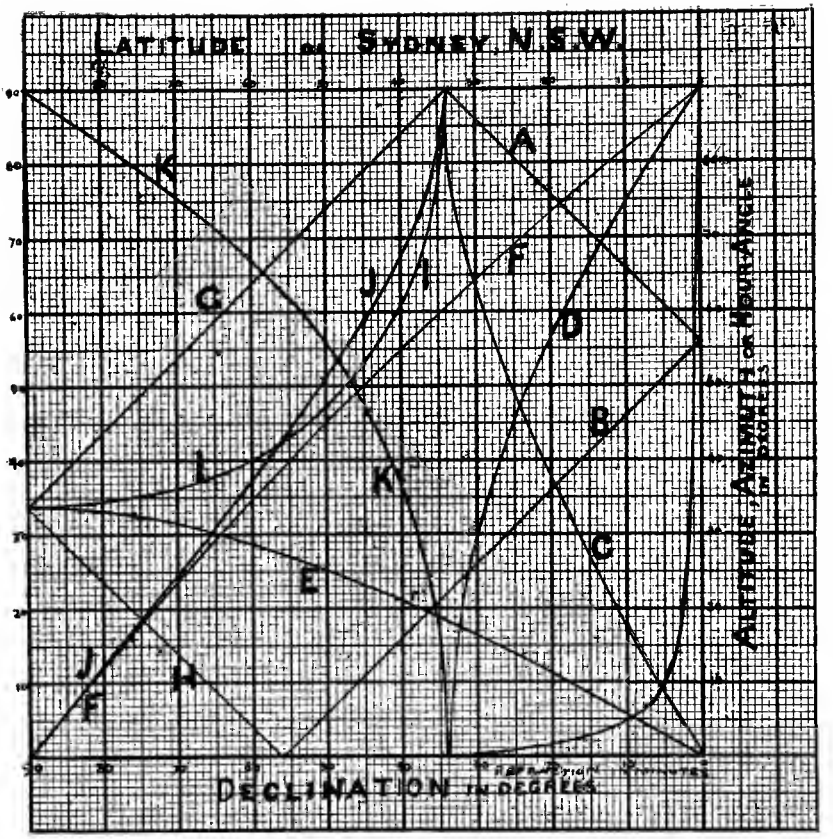


FIG. 4.

LET λ = LATITUDE; δ = DECLINATION.

A.	Meridional Altitude of Sun or Star of Southern Declination culminating Northwards ...	(1) Alt. $= 90° \quad \lambda + \delta$.
B.	Ditto of Northern δ culminating Northwards	(2) Alt. $= 90° - (\lambda + \delta)$.
C.	Altitude when Azimuth $= 90°$	(3) Sin. Alt. $=$ sin. $\delta \div$ sin. λ.
D.	Hour-Angle ,, ,, ,, ...	(4) Cos. H.-A. $=$ tan. $\delta \div$ tan. λ.
E.	Altitude when Hour-Angle $= 90°$...	(5) Sin. Alt. $=$ sin. $\delta \times$ sin. λ.
F.	Azimuth ,, ,, ,, ,, ...	(6) Cot. Azim. $=$ cos. $\lambda \times$ tan. δ.
G.	Meridional Altitude when culminating Southwards above the Pole	(7) Alt. $= \lambda + 90° - \delta$.
H.	Meridional Altitude when culminating Southwards below the Pole	(8) Alt. $= \lambda - (90° - \delta)$.
I.	Altitude of Circumpolar Star when at Elongation...	(9) Sin. Alt. $=$ sin. $\lambda \div$ sin. δ.
J.	Azimuth of Ditto	(10) Sin. Azim. $=$ cos. $\delta \div$ cos. λ.
K.	Hour-Angle of Ditto	(11) Cos. H.-A. $=$ tan. $\lambda \div$ tan. δ.

THE SYDNEY DIAGRAM.

Sydney, N.S.W. is nearly on the Latitude which is chosen for the construction of Philips' Planisphere of the Southern Hemisphere.

Diagrams of Stellar positions for the Southern Hemisphere are counterparts of those for the same Latitude in the Northern. The difference is solely in what the lines and curves represent of the observable celestial objects, differing both in identity and relative position. There is, however, hardly any place in the civilised world, probably no place in the British Empire, from which no stars of opposite Declination to its Latitude can be seen.

At Sydney, then :—

LINE A shows that no stars of Southern Declination culminating Northwards are within the range of the ordinary instrument.

LINE B shows that stars of Northern Declination culminating Northwards are observable when the Declination is between 1° and 56°, the latter just touching the Northern horizon. There are 60 stars of this class on the list. Both Aldebaran (α Tauri) and Vega, for instance are splendid objects at Sydney ; culminating at Altitudes of about 40° and 17° respectively. The Sun is also available for Meridional Altitude from the end of March to the middle of September.

LINE C shows that the Sun with Northern Declination and all stars up to 27° North Declination can be used for observation when the Azimuth is 90° East or West of the Meridian. This includes 37 listed stars.

LINE E shows that the Sun with Northern Declination and all stars up to 90° North can be used at Sydney when the Hour-Angle is 90°.

LINE G shows that circumpolar stars of Southern Declination 69° to 90° can be seen culminating above the Pole, this includes 4 listed stars.

LINE H shows that similar stars of 56° to 90° can be seen culminating below the Pole. This includes all but 2 of Whitaker's list for the Southern Hemisphere.

LINE I shows that stars 43° to 90° can be seen at Elongation. This includes all the 14 stars of Whitaker's list for the Southern Hemisphere. Proceeding to the illustration :—

Standard Time in New South Wales is 10 hours fast on Greenwich Time. The local Mean Time at Sydney is about 5 minutes fast on Standard Time, but this need not enter into our calculations. We will suppose for simplicity's sake that the observer's watch is set back 10 hours to Greenwich Mean Time after obtaining the exact Standard Time from the most reliable source in Sydney.

From the Table, p. 76 of Whitaker, we see that the local apparent time of sunrise was 5h. 33m. and of sunset 6h. 27m. On 15th October, the Sun's Declination is South, and from Line A we see that his Meridional Altitude is out of range ; therefore, for the purpose of getting the Latitude, we must have recourse to the stars.

It might be a matter of some importance to the Surveyor to complete his three observations the same night, and the stars would probably be unfamiliar to him. To be able rapidly to select the most suitable objects would therefore in such a case be essential to success.

Any stars culminating after sunset must, to suit his purpose be of Right Ascension more than that of the Sun by at least $6\frac{1}{2}$ hours. This at once shows where to begin searching in the list. Then, as to stars

culminating Northwards, we see from Line B that they must have a Northern Declination between 0 and 56°. This further limits the search. Again, as to stars culminating Southwards, we see from Lines G and H that those over the Pole must be of Southern Declination from 68° to 90°, and those culminating below the Pole from 57° to 90°. We see moreover from its Right Ascension that α Cygni (Deneb) will culminate shortly after sunset and from its Declination we see from Line B at a rather low Altitude. Possibly, by directing the telescope from the approximate data available, its culmination might just be caught. If not, α Pegasi (Markab) will be seen culminating at about 9½ p.m. local time and at a convenient Altitude.

In the next place, for determining the Meridian, we look up a star at Elongation, in this case to be visible a short time after we have made the first observation. If then we had been able to get the Latitude by means of Deneb, we could use a star for Meridian whose Hour-Angle at Elongation plus difference of Right Ascension from that of the Sun was more than 7 hours and the Altitude of which by Curve I was within range. These conditions would be met by α Tri. Aust. whose Elongation would be at about 8 p.m.

If, however, we had been obliged to wait for the Latitude by the culmination of Markab which occurred at about 9½ p.m. we should need a star whose Hour-Angle at Elongation plus difference of Right Ascension from that of the Sun exceeded the latter figure. These conditions would be met by α Pavonis which we see from Ephemeris and Diagram, will be at Elongation at about 11 p.m. Its Altitude also will be a convenient one. Proceeding then, as before, to calculate the Azimuth from Equation 10, we take the observation and correct the provisional orientation to the true North and South Line.

Finally, for the Longitude we find that α Arietis, culminating about midnight will best serve our purpose for the Longitude.

Supposing then that our watch is set on Greenwich Time, we make the following preparatory calculation with a view to the observation.

Right Ascension of α Arietis+24h. ...	26h.	2m.	42s.
Sidereal Time Mean Noon Greenwich ...	13	34	51
Sidereal interval at Greenwich from Noon to culmination	12h.	27m.	51s.
Retardation ...		2	2·5
Mean Time of α Arietis culmination at Greenwich	12h.	25m.	48·5s.

We then set the instrument to the true Meridian as found by the previous observation, and to the approximate Altitude from the Diagram or preferably to the exact Altitude from Equation 2, plus correction for refraction, timing the transit by Greenwich Time by watch.

Supposing this to take place at	2h.	22m.	50s.
The difference in Mean Time between culminations of α Arietis at Greenwich and the place of observation will be ...	10h.	2m.	58·5s.
Acceleration ...		1	39
The above difference in Sidereal Time ...	10h.	4m.	37·5s.

10h. 4m. 37·5s. in angle = 151° 9′·4 East Longitude.

STELLAR POSITIONS
IN ALL
LATITUDES
AND
BOTH HEMISPHERES.

In the following diagrams, the approximate stellar positions given by the curves C, D, E, F, I, J and K of the previous diagrams can be found at a glance, for any required Latitude and Declination. The time is thus saved of a merely tentative calculation to determine whether any particular star is convenient for observation at time and place.

The curves are given for every five degrees of Latitude up to 65 degrees. Intermediate values can be roughly estimated proportionally.

EAST AND WEST STARS.

Stars bearing due East and West, including the Sun, that is to say, whose Azimuth is 90° East or West of the Meridian, are observable when their Declination is of the same name as, but of less amount than, the Latitude of the place. Fig. 5 shows the Altitude and Hour-Angle of

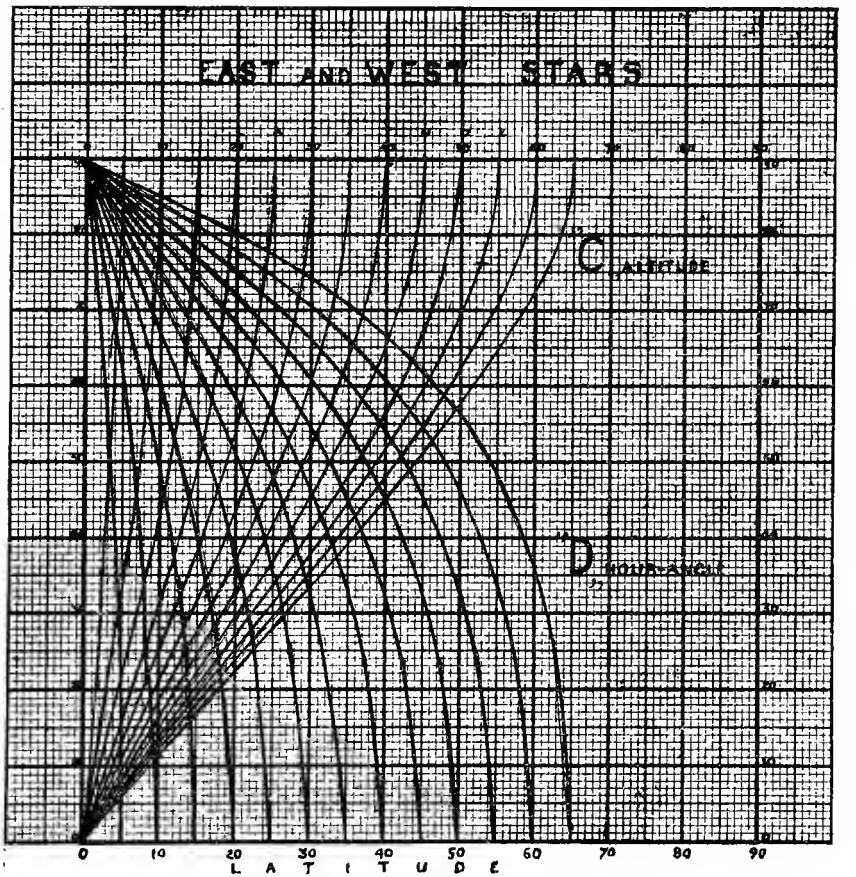


FIG. 5.

stars in this position. Curve C gives the Altitude, found by Equation 3, in Latitudes read on the upper horizontal scale. The curve is followed up to its intersection with a vertical from the star's Declination read on either of the horizontal scales. The intersection point is opposite to the Altitude, read on either of the vertical scales. Curve D gives the Hour-Angle, found by Equation 4, in Latitudes read on the lower horizontal scale. The curve is followed up to its intersection and the Hour-Angle read similarly to the instruction for Curve C.

Reduced to time, the Hour-Angle in the case of a fixed star is a sidereal interval; in the case of the Sun, an interval of Solar apparent time.

An equatorial star, *i.e.*, one whose Declination is zero, when due East or West, is on the horizon with an Hour-Angle of 90°.

EXAMPLE.

In Latitude 30° S., near Durban, required the Altitude and Hour-Angle of Sirius (α Can. Maj.) when due East. The Declination of Sirius is, roughly, $16\frac{1}{2}$° S. Following the preceding instructions, we read the Altitude and Hour-Angle opposite the two intersections as approximately 35° and 59° respectively. The exact position by calculation is 34° 52′·2 and 58° 53′·4.

SIX-HOUR STARS.

Stars, whose Hour-Angle is 90°, *i.e.*, which are six sidereal hours

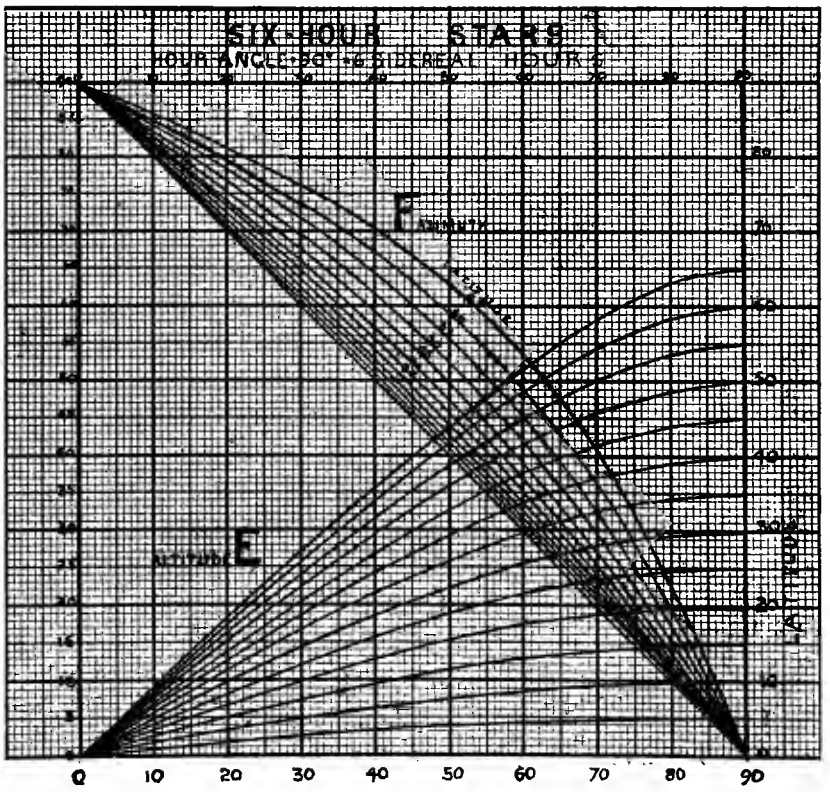


FIG. 6.

from the Meridian, may be observed when their Declination is of the same name as the Latitude.

The Altitude is always less than the Latitude and less than the Declination. At the Equator, the Azimuth of a " Six-Hour Star " is the complement of its Declination, and is greater than that complement as the Latitude increases.

The Curve E, Fig. 6, giving the Altitude by Equation 5, relates to the Latitude of the observer, read on the right-hand vertical scale. This curve is followed up to its intersection with the vertical from the star's Declination, read on the horizontal scale. This intersection is opposite to the Altitude read on one of the vertical scales.

The Curves F, arched and headed by the word " Latitude," are for the corresponding Azimuths, and are numbered, as far as possible, with the Latitudes to which they refer. The curve is followed up to an intersection, and the Azimuth read similarly to the instruction for Curve E.

EXAMPLE.

On June 1st, 1921, in Latitude 50° N., the Sun's Declination being about 22° N., required its approximate Altitude and Azimuth when the Hour-Angle is 90°. The intersections on the diagram are found opposite $16\frac{1}{2}°$ and 75° respectively. The figures by calculation are 16° 41′ and 75° 26′.

The Sun being, under these circumstances, too high at its culmination for a transit observation, the position either at an Azimuth or Hour-Angle of 90° is very convenient for correcting the watch at a Base Station.

CIRCUMPOLAR STARS AT ELONGATION.

Circumpolar Stars are observable at Elongation whose Declination is of the same name as, and greater than the Latitude of the observer. The Altitude is always greater than the Latitude. When the Declination is equal to the Latitude, the star has an Altitude at Elongation of 90°. As a general rule, the Declination must be considerably more than the Latitude to bring the star within the range of the vertical limb of the instrument when at Elongation.

In the Northern Hemisphere, Polaris is the most convenient star. In the Southern, Achernar (α Eridani) or α Centauri. The apparent places of all these stars are given in " Whitaker."

The diagram Fig. 7 of Altitude, "I,, calculated from Equation 9, is found from the intersection of any one of the curves of Latitude with the vertical from the Declination read on the horizontal scales. This intersection is opposite to the Altitude read on one of the vertical scales.

In the diagram Fig. 8 the Azimuth "J,, and Hour-Angle, "K,, calculated from Equations 10 and 11, are found from intersections similarly to the previous instructions.

EXAMPLE.

In Latitude 45° N., required the Altitude, Azimuth and Hour-Angle of Dubhé (α Urs. Maj.) at Elongation. The approximate Declination being 62° N., the intersections are found opposite $53\frac{1}{2}°$, $41\frac{1}{2}°$ and 58° respectively. The exact calculations are :—

Altitude	...	...	...	53° 42′·03
Azimuth	...	...	...	41° 19′·4
Hour-Angle	...	...	...	58° 8′·3

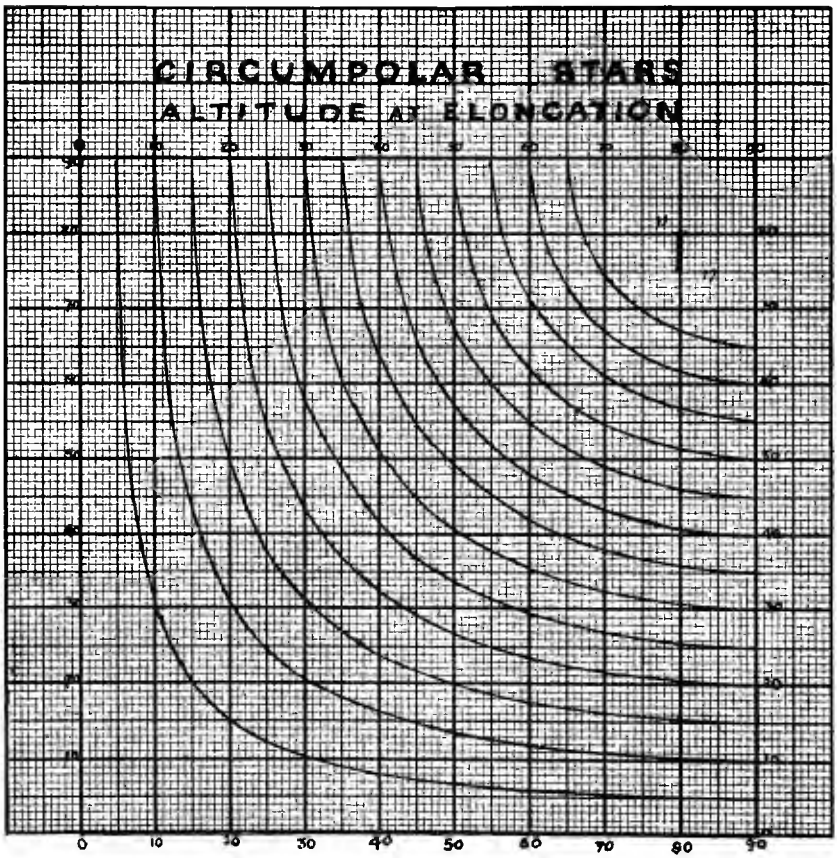


FIG. 7.

Geodetic Astronomy, unless continuously in use, is very rapidly forgotten. Some, who only have occasional use for it, are liable to be suddenly called upon to do so. The Graphic Representation of Stellar Positions refreshes the memory more quickly than turning up the theory in the text books.

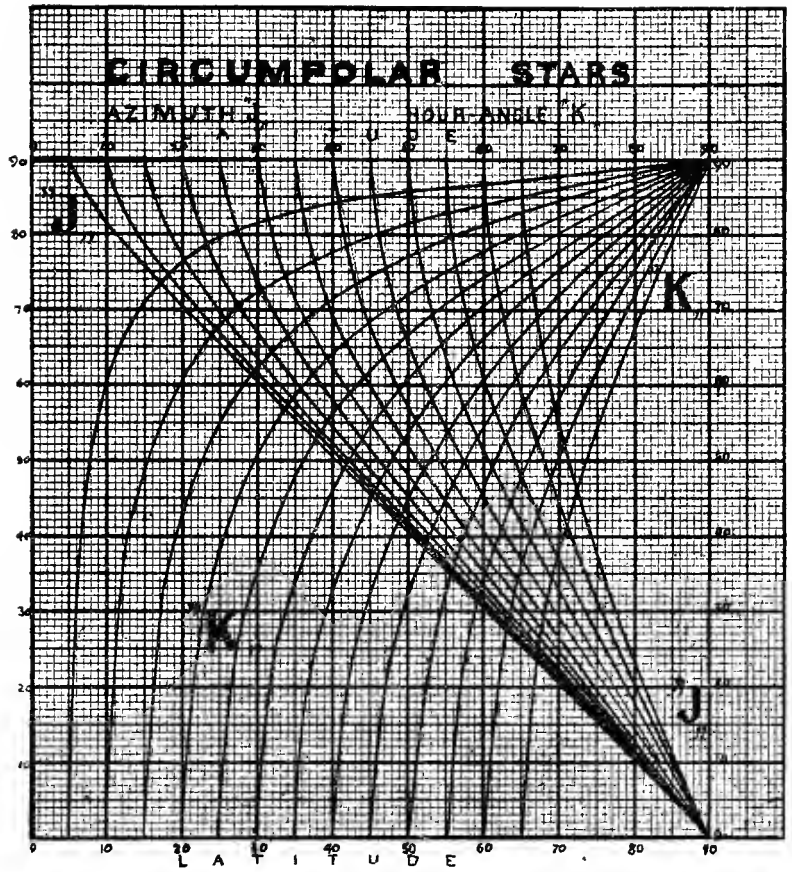


FIG. 8.

"Graphpaper" is now published of a size which would admit of diagrams being constructed for any particular Latitude, of ten times the size of those given here, and therefore with ten times the degree of accuracy. In most cases, however, the stellar position is only required with complete accuracy for one of its elements, which must be calculated from the corresponding Equation. The other elements, for finding the star, are then given with sufficient accuracy from the small diagram.

Telegrams, "Potter, Minories, London."

J. D. POTTER,

ADMIRALTY AGENT FOR CHARTS,

AND

PUBLISHER OF NAUTICAL WORKS.

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145. MINORIES.

LONDON, E. 1.

ADMIRALTY CHARTS.

INCORRECT CHARTS.

The attention of the Board of Trade has frequently been called to cases in which British vessels have been endangered or wrecked through Masters attempting to navigate them by means of antiquated or otherwise defective Charts.

The Board of Trade desire, therefore, to direct the especial attention of Shipowners and their Servants and Agents to the necessity of seeing that the Charts taken or sent on board their Ships are corrected down to the time of sailing. Neglect to supply a Ship with proper Charts will be brought promiently before the Court of Inquiry in the event of a wreck occuring from that cause.

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J. D. Potter undertakes the examination of Ships' sets of charts after every voyage, or at stated periods; and will report to the Owners the necessary new editions required to bring the sets up to date. The fee for this examination is 21/- per 100 charts.

J. D. Potter does not undertake the correction of these old charts.

ALTERATION IN SYSTEM OF DATING CHARTS FOR CORRECTIONS.

Date of alteration.—Notices dated 1st May 1918.

The existing system of dating Admiralty charts for Admiralty Notices to Mariners is to be superseded by the following :—

When a chart is corrected for an Admiralty Notice to Mariners, the year and the number of the Notice is to be inserted in the bottom left-hand corner of the chart, thus :—1918—**2, 17, 46,** etc.

Remarks —Charts which have been cancelled for any cause other than the issue of a new edition, will carry in the bottom left-hand corner in brackets the date of such cancelling, thus :—

1918—**2, 17, 46** (X. 21) **50, 62,** etc. ; 1919—(I. 26). **40, 72,** etc.

Notations enclosed in square lines thus : 6.18 *are references for use at the Admiralty only.*

ADMIRALTY CHARTS.

INTERNATIONAL HYDROGRAPHIC CONFERENCE

Report of the Proceedings, June 1919 - - . 10/6

(See top of page 5.)

A 16 page Pamphlet (Gratis).

Information for the Correction of British Admiralty Charts and Hydrographic Publications.

Mariners and others are invited in the interests of navigation to forward to the Hydrographer, Admiralty, London, S.W., any information that may come under their notice, which would be useful for the correction of the Charts and other Hydrographic Publications issued by the British Admiralty; EARLY advice as to newly discovered dangers, the establishment of, and changes in, any aids to navigation is specially requested.

Copies of a form (H. 102) on which to render information can be obtained GRATIS from the Admiralty Chart Agent—

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ADMIRALTY CHARTS.

Probably there are but few persons connected with the Nautical World who have not heard of the Hydrographic Department of the Admiralty. A large number, however, must naturally be unaware of the immense amount of work done by the Officers associated with this vast but unpretentious establishment—vast on account of the wide scope of its operations, unpretentious by reason of the quiet and business-like way in which the whole of its important duties are carried out. On the second floor of the new building in Whitehall, known as the Admiralty, are to be found the Officers who painstakingly inform "those who go down to the sea in ships" where they can navigate their vessels in safety, and where they cannot do so.

It appears from the "Encyclopædia Britannica" that nautical (loxodromic or compass) maps made their first appearance in Italy in the 13th century, the oldest which has been preserved coming from Pisa, and belonging to the middle of that century, and when the loxodromic maps came into existence, handbooks with sailing directions accompanied them. In England the word "map" became applicable only to a land map, and the sea map became known as a "chart." As early as the 14th century this expression appears to have been used to distinguish a sea map, but it is stated it did not become general till the 16th century. In 1583 one Lucas Janszoon Waghenaer, of Enkhuyzen, who belonged to the School of Mercator, became the founder of nautical map collections. In Holland a Cartographer to the States-General was appointed in 1633, and it was his duty to examine the ships' logs and so amend the maps

Prior to 1795 the Royal Navy of England and its Mercantile Marine were dependent for their supplies of charts and sailing directions, upon surveys made by Captains Cook, Lane, Gould, Hurd (afterwards Hydrographer), Vancouver (one of Cook's best lieutenants), Flinders, and Mackenzie. Up to about 1790 the surveys made appear to have been of a semi-official character notwithstanding the fact that those engaged in the work were employed and paid by the Admiralty.

By an Order in Council in the year 1795, a Hydrographical Office was established, and a Hydrographer appointed, whose duties, as defined by the said Order were "to take charge and custody of such plans and charts as then were, or should thereafter be, deposited in the Admiralty, and to select and compile such information as might appear to be requisite for the purpose of improving navigation."

The gentleman selected by Earl Spencer in 1795 for the post of first Hydrographer was Mr. Alexander Dalrymple, an officer in the East India Company's Service.

In 1786 the Catalogue of that Company comprised 347 Charts between England, the Cape, India, and China.

Mr. Dalrymple commenced his official duties at the Admiralty with one assistant and a draughtsman.

It may be interesting to give the Staff of Officers at present (1920) engaged in this Department:—

The Hydrographer, Assistant Hydrographer, Chief Civil Assistant, Superintendent of Charts Assistant Superintendent of Charts, Superintendent of Sailing directions, Superintendent of Chart Issues, Superintendent of Meteorological Branch, Superintendent of Tidal Work, twelve Naval Assistants to the Hydrographer, Director of Navigation and seven Assistants, sixteen Cartographers, Staff Clerks Second Division Clerks, Assistant Clerks, Draughtsmen. Women Clerks and others; total exceeds One Hundred and Fifty Officials.

The valuable work performed by the Hydrographic Department of the Admiralty may be gleaned from a perusal of the Report of Proceedings of the International Hydrographic Conference London, June, 1919 (published by His Majesty's Stationery Office, 1920) when Fifty-one Delegates representing Twenty-five States attended in General Meeting at the invitation of the British Government. This Report will be found most interesting reading to the Nautical profession. It contains over two hundred pages of evidence and reports dealing with the examination of many questions of practical and scientific interest in connection with navigation and marine survey, and is a comprehensive summary of the proceedings of one of the most important international conferences held for the purpose of improving the hydrographic services of the Governments of the Maritime States.

In 1919 there were eight Surveying Ships and various Dockyard Launches employed in Hydrographical surveys in many parts of the Globe. The number of officers and men engaged being about nine hundred.

During the ten years 1910–1919 no fewer than four thousand five hundred and forty six rocks and shoals dangerous to navigation were reported.

The general public have little knowledge in regard to the system upon which not only the Admiralty Charts are compiled and distributed, but kept up-to date. A chart is in one sense never complete. The ocean, like the land, is subject to constant physical changes, and discoveries of new or unknown dangers to navigation are continually taking place. It is, therefore essential that every chart issued under the authority of the Admiralty should be absolutely correct at the date on which it is sold, so far as the information to hand up to that date permits. The primary function of the surveying service and the Hydrographic Office is to compile and issue charts for the use of His Majesty's ships, but those in authority are fully alive to the fact that correct charts are a *sine qua non* for the merchant service, and that the merchant service is not in a position to supply itself with such charts. The Admiralty, accordingly, made provision for the public wants in this respect, and with this end in view appointed an Agent, whose duty it is to sell all Charts, Sailing Directions, Light Lists, and other publications issued by the Hydrographic Office.† In addition, there are numerous Sub-Agencies in all the principal Home and Foreign Ports where these Publications are always to be obtained.

The Admiralty Charts are used not only on board almost every vessel of the British mercantile marine, but in the Navies of many foreign countries and nearly all the merchant vessels of the world, whatever flag they may fly. The work of the Surveying Department of the Navy, whether on board the vessels specially detailed for surveying duties or in the Hydrographic Office at the Admiralty, is accordingly, work of very considerable importance.

There are already published over three thousand eight hundred charts; and this number is being added to by new charts at the rate of about fifty each year. In 1830 the first official Catalogue of Charts was issued, and the total number of Charts then catalogued was 962.

From the figures shown on page 19 some idea may be formed of the extent of the work done by this Department, and the very large increase which has taken place in it during the last forty years.

Tide Tables, Light Lists, Distance Tables, and Books of Sailing Directions have been issued for every sea. These publications are in very great request by the Mercantile Marine and Foreign Naval Powers, and many thousands of copies are yearly required to meet these demands. The British Admiralty, of course, retaining large quantities for the needs of the Royal Navy.

The Notices to Mariners issued by the Hydrographer in the year 1885 amounted to 243. Ten years later the figures had grown to 738 of such Notices; for the year 1905, 1,392 were necessary and in 1919 there were 2,311 issued.

Other interesting particulars could be furnished respecting the work of this Department, and those desiring additional information should obtain the pamphlet "On the Correction and Use of Charts, &c.," to be had free of charge from the Admiralty Agent.

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† J. D. Potter, 145, Minories, London E. 1.

LIST OF NAUTICAL WORKS.

PUBLISHED BY

J. D. POTTER.

In submitting this catalogue of Nautical Works to students and others, the Publisher would remind them that as the titles of books sometimes give but an imperfect idea of contents, he has invoked the aid of an expert of long and varied experience in Navigation and kindred subjects to somewhat amplify the information given on the title pages of some of the vols., which will assist in the better selection of books.

ALTITUDE TABLES.

Computed for Intervals of Four Minutes between the Parallels of Latitude 31° and 60° and Parallels of Declination 0° and 24°, designed for the Determination of the Position Line at all Hour Angles without Logarithmic Computation, by *Frederick Ball, M.A.* (*late Scholar of Exeter College, Oxford*), *Chaplain and Naval Instructor in His Majesty's Fleet* 18 0

Ditto, ditto, between the Parallels of Latitude 0 and 30° and Parallels of Declination 0° and 24° 18 0

Ditto, ditto, between the Parallels of Latitude 24° and 60° and Parallels of Declination 24° and 60° 18 0

These Tables are so arranged for working by the New Navigation that only one correction has to be applied to the altitude taken direct from the book. The entire logarithmic work is replaced by a single subtraction and the application of the correction. In conjunction with the Nautical Almanac all the usual problems of Navigation are solved.

Amongst others the time of Sunrise, the Altitude Azimuth, Course and Distance on a Great Circle, etc.

(*The Tables have been adopted for use in the Japanese Navy.*)

Altitude and Azimuth Tables, for Facilitating the Determination of Lines of Position and Geographical Position at Sea. The simplest and readiest in solution. Plane and Spherical Traverse Tables for solving all problems of navigation. By *Lieut. Radler de Aquino* (Brazilian Navy). All sights for position are worked out by the same method *without logarithms*, with hardly any calculation. All the other problems in navigation are easily and rapidly solved by inspection without interpolation. This work has received the favourable endorsement of the United States Hydrographic Office. 2nd Stereotyped Edition 12 0

New Log and Versine Altitude Tables (Reprinted from the 2nd Edition of above Book), by *Lieut. Radler de Aquino* (Brazilian Navy). The simplest and readiest way of finding the Altitude by means of *logarithms* 2 6

A New Altitude-Azimuth-Hour-Angle Chart. This new invention does for the Altitude-Azimuth problem what the well known Weir diagram accomplishes for the Time-Azimuth method 2 6

By means of a simple chart, or diagram, which represents a square, with sides divided according to the values of the Natural Haversine, the Altitude Azimuth is solved by merely drawing a straight line. Or again with the same data, latitude, declination and altitude, an approximate value may be found for Hour Angle. It is anticipated that the diagram, the invention of which is due to Mr. W. G. Littlehales, of the U. S. Hydrographic Department, will prove of great service in the Navigation of the Air.

Aquino's Protractor Diagram. A very remarkable development of the use of squared paper for chart work, as simple as it is ingenious. Issued in blocks of 100 ... ... 8 0

This diagram offers the simplest possible method of laying off position lines. The work is done more quickly, and more accurately, and the use of a protractor is dispensed with.

List of Nautical Works published by J. D. POTTER.

DOUBLE ALTITUDES.

s. d.

A Method for finding the Latitude by the Simultaneous Altitudes of Two Stars, by *Capt. Burdwood, R.N.* (reprinted 1896) 1 0

COOKERY.

Ship's Cook and Steward's Guide, containing Hints for Management, and Two Hundred and Fifty Recipes, by *James B. Wilson* 1 0

TIME AZIMUTH TABLES.

Sun's True Bearing or Azimuth Tables, by *John Burdwood, (Staff Commander, R.N., of the Hydrographic Department, Admiralty.)* The **Revised** Edition of the above, with Extensions in Latitude, Declination and Hour-Angle, has been prepared, with the permission of H.M. Stationery Office, by *Percy L. H. Davis, F.R.A.S., Chief Assistant (retired) in H.M. Nautical Almanac Office* 20 0

Code Name DAVIS 2.

Sun's True Bearing or Azimuth Tables, by *John E. Davis (Staff Commander, R.N. of the Hydrographic Department, Admiralty).* The **REVISED** Edition of the above, with Extensions in Declination and Hour-Angle, has been prepared by *Percy L. H. Davis, F.R.A.S., Chief Assistant (retired) in H.M. Nautical Almanac Office.* 20 0

In this completed edition of the older book, azimuths are given from the horizon to the meridian, an improvement rendered necessary by the very general use of the Marcq St. Hilaire method.

Code Name DAVIS 1.

Davis's Supplementary Azimuth Tables (now published separately). The Time Azimuth Tables in general use do not often give azimuths near the meridian, which are in frequent demand for ex-meridian observations, but they will be found in this book, in addition to complete tables extending to latitude 64° 10 0

(Supplied to H.M. Fleet by Admiralty order)

Davis's Star Azimuth Tables, computed for all latitudes between **60° North** and **60° South,** by *P. L. H. Davis.* This book has followed on the very general adoption of stellar observations as a means of navigation, and supplies the seaman with the same details regarding stars, as he can get from "Burdwood and Davis" when the sun is concerned. Some ingenious altitude marks are used for the first time in these tables which materially aid in the identification of any hastily observed star, as to which doubt may exist 20 0

(Supplied to H.M. Fleet by Admiralty order.)

High Latitude Tables, between 61° and 78°. By *Percy L. H. Davis* 10 0

This work, which was originally prepared for and used by the Antarctic Expedition of 1901, has now been adopted for use in H.M. Navy and will certainly be a necessity in all ships trading to northern ports.

(Supplied to H.M. Fleet by Admiralty order.)

A complete set of the above Tables, dealing as they do with all declinations up to 64°, and with practically all navigable latitudes, have the effect of rendering the Time Azimuth, considered as a logarithmic problem, obsolete. The extensions of the Azimuth Tables effected by Mr. Davis have a second important result, that they render the solution of the problem of finding Course upon a Great Circle perfectly general, so that such a course is now more easily determined than the ordinary Mercator Course. For examples see footnote to page 136 of Raper's Practice of Navigation (1920 edition.)

Short, Accurate, and Comprehensive Altitude-Azimuth Tables to show the true bearing of the Sun, Moon, Planets, &c., for latitude 0° to 75° north or south; altitudes 0° to 75°; and declination 30° north to 30° south; also the Approximate Ship Time, by *A. C. Johnson, R.N.* (Published by request) 3 6

(Supplied to H.M. Fleet by Admiralty order.)

List of Nautical Works published by J. D. POTTER.

Captain Weir's Azimuth Diagram 1 6
(Supplied to H.M. Fleet by Admiralty order.)

Time Azimuth Diagram, by *Hugh Godfray, M.A.* 3 6

CHARTS.

Charts: their use and meaning, with thirteen figures and eight charts, by *Dr. G. Herbert Fowler* 4 0

This, which is believed to be the first book on charts yet published, brings together information which hitherto has been obtainable only from verbal teaching. It deals with Mercator and Gnomonic navigational charts, and with Meteorological and other scientific charts, from a practical point of view in simple language.

CHRONOMETER TABLES.

Davis's "Chronometer" Tables; or, hour angles for selected altitudes between latitudes 0° and 50°, with variations for 1′ in all elements, by *P. L. H. Davis.* Means of working a Sun "Chronometer" arithmetically have been for many years a desideratum, and have been published, in 1793, by Lalande; in 1827, by Lynn; and by Hommey, in 1863; but Mr. Davis, by the omission of useless or undesirable altitudes, and the inclusion of Variations in 1′ of Altitude, Latitude, and Declination, has made a table of great practical utility. The book, as a substitute for or a check on logarithmic calculation, is almost a necessity, and is especially useful in latitudes less than 45°. A comparison has been made in actual work of the tabular results with those obtained in the ordinary way, showing practically identical results 20 0

The general adoption of the Position Line methods has added greatly to the advantage gained by this method of finding hour angle by simple arithmetic, for the following reasons. By working with the whole degree of latitude nearest to the latitude by account we dispense with the correction for latitude altogether, thus saving one third of the work. If in addition to this we make the observation upon a complete degree of altitude, as is generally possible in moderately fine weather, a second calculation is eliminated, and by means of the "variations" alluded to above the hour angle is found with no more trouble than is presented by the correction of an element from the Nautical Almanac. Captain Hommey who, as already mentioned, published a set of Chronometer Tables in 1863, strongly recommended the use of an exact degree of altitude in connection with the Tables.

Notes on the Management of Chronometers and the Measurement of Meridian Distances, by *Rear-Admiral Charles Shadwell F.R.S.* (1861) 4 6

EQUAL ALTITUDES.

Tables for Facilitating the Method of Equal Altitudes, by *F. A. L. Kitchin, B.A., Naval Instructor, R.N.* 1 0

COMPASS.

Rev. William Hall's Visible Astronomical Compass. for Lat. 50. Channel and adjacent zone. Important for sea and air navigation, size, 6in. diameter 1 0

An Explanation of the Adjustment of Ships' Compasses, illustrated with numerous diagrams, by *Captain the Honourable Wentworth Chetwynd, R.N.* ... 2 0

The work consists of a reproduction of a course of lectures delivered by the author at the Royal Naval College Greenwich in the year 1904, and the manner in which a clear and comprehensive view of the whole subject is compressed within the limits of a small volume is not a little remarkable. One great charm of the work is its originality, and another is the evident desire apparent throughout not to be content with stating a fact, but whenever possible to find a reason for it. However wide a student's reading may have been in this somewhat thorny subject he will find in this little volume matter for fresh reflection.

Handbook to Beall's Compass Deviascope, by *Captain George Beall,* contains, in addition to a complete explanation of this well-known instrument, much information necessary to compass correction ... ... (4th Edition). 1 6

No one man probably has done so much to disseminate a sound knowledge of the mysteries of compass correction as has been accomplished by Captain Beall by means of his great invention. In this little handbook are described the various uses to which the Deviascope can be directed, together with a large amount of general information upon the subject of compass correction generally.

List of Nautical Works published by J. D. POTTER.

ADJUSTMENT OF COMPASSES.

	s.	d.
Elementary Manual for the Deviations of the Compass in Iron Ships, intended for the use of Seamen of the Royal Navy and Mercantile Marine, and Navigation Schools, by *E. W. Creak, C.B., F.R.S., retired Captain, R.N.*	10	0

Every seaman was familiar with the official "Admiralty Manual for the Deviations of the Compass," now withdrawn from sale. The first edition of this work was issued as far back as 1862, and the technical portion was largely based on the researches of a distinguished Mathematician, the late Archibald Smith. The mathematical character of the contents, however, placed the volume to a great extent beyond the comprehension of the ordinary navigator, and later on an "Elementary Manual" was issued. It fell to the lot of Captain Creak, in the course of his official duties in the Compass Department at Whitehall to recast this useful work, "both in the manner of presenting its subject to seamen, and in the arrangement of its parts." In its present form the treatment of the Deviation is distinctly simpler, and while the larger portion of the book is quite intelligible to the beginner, at the same time the volume includes all the information that the more advanced student is likely to require.

Practical Information on the Deviation of the Compass, for the use of Masters and Mates of Iron Ships, by *J. T. Towson, F.R.G.S.* .. ..

AND

Supplement to the above; being the Questions on the Deviation of the Compass issued by the Board of Trade for the Examination for Masters' and Extra Masters' Certificates, and Answers to the Questions, by *Capt. William Mayes, R.N.* ... ... — 4 0

The Roxburgh Compass Error Card. For quickly and accurately correcting True and Compass Courses and Bearings by a New Method; extremely simple and easy to work. Size 10 × 11 inches, printed in black and red; varnished. By *C. R. Wylis* ... ... — 3 0

The Pocket Compass Corrector. Makes an error in applying variation and deviation almost impossible ... ... — 3 0

The Binnacle Compass, Corrected by itself, or the Deviation found with one Compass by both methods, and the Corrections applied, by *Capt. A. B. Becher, R.N.* — 1 0

The Storm Compass, or Seaman's Hurricane Companion, containing a familiar explanation of the Hurricane Theory, by *Capt. A. B. Becher, R.N.*, illustrated with Diagrams and Accounts of Hurricanes ... ... — 1 6

Plain Deviation Curve Diagram, by *Captain J. C. Robinson* ... ... — 0 6

GREAT CIRCLE SAILING.

A Chart of South Latitudes, beyond 20 degrees, to facilitate the practice of Great Circle Sailing; with an accompanying diagram for the determination of the courses and distances, by *Hugh Godfray, M.A.* ... ... — 3 0

LATITUDE BY EX-MERIDIAN TABLES.

Davis's Ex-Meridian Tables and Supplementary Azimuths, by *P. L. H. Davis.* This important work contains Calculated Reductions to the Meridian for hour angles less than 75^m and altitudes lower than 84°, Declinations and Latitudes 34° and 64° N. and S. The use of the book is quite easy to anyone familiar with the Azimuth Tables. The Supplementary Azimuths, which accompany it, give bearings too near the meridian for inclusion in "Bordwood and Davis," which are now in great request for position lines and ex-meridian work 20

Amongst the great number of Ex-Meridian Tables that have been submitted to the public in recent years the Davis Tables occupy quite a unique position, for the following reason. The ordinary procedure is to obtain from an approximate formula the main correction and if an accurate solution is desired, to refer to a Second Difference Table for a supplementary quantity. The Davis Tables however are deduced from a rigorous formula of Spherical Trigonometry, which supplies the whole correction at once, with practically the same accuracy as would result from logarithmic calculations. The fact that the Reductions may be employed with equal facility in the application of the Marcq position line methods adds materially to the value of the work, while the "Supplementary Azimuths," bound up with the Reductions, offer the great convenience of obtaining Reduction and Azimuth from the same volume.

Tables for the Reduction of Ex-Meridian Altitudes, by *J. T. Towson, F.R.G.S.* — 1 0

Ex-Meridian Diagram, by *F. A. L. Kitchin, B.A., Naval Instructor, R.N.* ... ... — 1 0

HOUR ANGLES.

See Davis "Chronometer Tables," page 9.

List of Nautical Works published by J. D. POTTER.

HYDROGRAPHICAL ENGINEERING.

An Essay on Hydrographical Engineering, as applicable to Floating Sea Barriers, Harbours, Batteries, Coast Defences, and Naval Fortifications, by *Capt. Addsrly Sleigh, K.T.S., F.R.S.L.* (with Illustrations), (1859) 10 0

INTERPOLATION.

Notes on Interpolation, Mathematical and Practical, by *Rear-Admiral C. Shadwell F.R.S.* 2 0

LATITUDE AND LONGITUDE.

On Finding the Latitude and Longitude in Cloudy Weather and at other Times, by *A. C. Johnson, R.N.* Enlarged to 56 pages, with Appendix and Part II. 6 0

Short Tables and Rules for finding Latitude and Longitude, by Single and Double Altitudes, Pole Star, Lunars, &c., by *A. C. Johnson, R.N.* 3 0

Scales of Latitude from 5° to 60° proportional to a scale of Longitude, where ½ in. = one mile, arranged to facilitate the finding of position from two Sumner lines, by *R. E. Peake, A.M.I.C.E.* ... ... per set 5 0

Tables showing the Length in Feet of a Degree, Minute, and Second of Latitude and Longitude, with the corresponding number of Statute Miles in each Degree of Latitude; and the number of Minutes of Latitude or Nautical Miles contained in a Degree of Longitude, under each Parallel of Latitude, by *R. C. Carrington, F.R.G.S.* (1868) 1 0

LAW.

Handbook on the Law and Practice relating to Apprentices to the Mercantile Marine Service, by *F. W. Gardner* (of the Middle Temple) ... 1 6

LIGHTS.

Light Range Table (height of light, 10 to 1000 feet; and height of eye, 10 to 120 feet), compiled and arranged by *J. S. Commander, Master Mariner* 0 6

Lights in Lyrics, or a Glance at the Channel Lights as Piloting Marks, on a run from Scilly to the Nore, accompanied by a Parting Precept on **Compass Deviation,** addressed to all younger Mariners. With a view of the Casquets, Notes and Charts. (1859) 1 0

LUNARS.

Notes on the Reduction of Lunar Observations, Mathematical and Practical, by *Rear-Admiral C. Shadwell, F.R.S.* (1881) 4 6

See also **Latitude and Longitude.**

LOGARITHMS.

Davis's Requisite Tables (Logarithmic), by *P. L. H. Davis.* Tables of Logarithms to five places of decimals only, for practical sea work. The typography and arrangement of the book will render it suitable for habitual use, and it contains a table of Logarithmic and Natural Haversines specially designed for modern navigation 7 6

Davis's Five-Figure Logs and Anti-Logs, by *P. L. H. Davis.* Specially prepared for use in Actuarial and General Calculations. These tables are very legible and do not fatigue the eye in use 5 0

Ditto ditto ... ... with Index Tabs... ... ... 6 0

List of Nautical Works published by J. D. POTTER.

MAST-HEAD ANGLES.

Tables of Mast-Head Angles, for five feet intervals, from 30 to 280 feet, and varying distances from a cable's length to four miles, with their application to Nautical Surveying; also the determination of distance by sound, with an example... ... s. 2 d. 0

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Foreign Measures and their English Values, compiled from Official Sources, by *R. C. Carrington, F.R.G.S.* (1864) 7 6

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A Voice from the Quarter-Deck on the State of our Mercantile Marine, by *Joseph Mayne* (Master Mariner) (1876) 1 0

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METEOROLOGY.

Solectrics; a theory explaining the causes of Tempests, Seismic and Volcanic Disturbances, and how to calculate their time and place. Illustrated by over 150 diagrams, by *Alfred J. Cooper*, Navigator. (Second Edition) 6 0

The Causes of Weather and Earthquakes (with four Diagrams), by *Alfred J. Cooper* (1902) 2 0

These works relate to a subject which is still in its infancy, but of which more will undoubtedly be heard in years to come. The remarkable manner in which definite forecasts of the author have been fulfilled from time to time cannot be ascribed to mere coincidence, and the books have aroused considerable interest, not only amongst nautical men, but with the general public also.

Light as a Motive Power, a Series of Meteorological Essays (1875), by *Lieut. R. H. Armit, R.N.* 15 0

See also **Winds.**

REVERSIBLE TRANSIT INSTRUMENT.

Notes on the use of the Portable Reversible Transit, and the Method of Calculation of the Observations, with diagrams and photographs, by *Capt. C. E. Monro, R.N.* 3 0

ROYAL NAVY.

Chart of the Navy of Great Britain, from the Earliest Period of History, compiled from Historical publications, old records, Parliamentary returns, and other authorities, by *Frederick Perigal* (of the Admiralty), 1860 ... ... 3 6

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The Rules of the Road at Sea, comprising the Regulations for preventing collisions at Sea, 1897, and Rules in force in Harbours, Rivers, and Inland Waters; with explanatory notes and observations. by *H. Stuart Moore, of the Inner Temple and the Admiralty Court, Barrister-at-Law.* (Third Edition) 10 0

3 H (How's Her Head) Indicator and Rule of the Road at Sea, by *George Spillane* 1 0

List of Nautical Works published by J. D. POTTER.

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The Alpha, Beta, Gamma Navigation Tables, solving all the problems used in fixing position lines by rules derived from a single formula of Spherical Trigonometry, by *H. B. Goodwin, M.A., F.R.A.S.*	8	0
The "Conway" Manual of Navigation. In this book of 80 pages nothing is taken for granted. All formulas are proved and the dependence of Navigation and Nautical Astronomy upon the solution of Plane and Spherical Triangles is clearly brought out. Particular emphasis has been laid upon method. By *J. Morgan, M.A. (Senior Master) and T. P. Marchant, A. L. Wood (Navigation Masters), H.M.S. "Conway" School Ship*	5	0
Such a compilation as this, compiled by men of great experience in the teaching of nautical subjects for use on board the "Conway," should be very useful also to candidates prepariog for the Board of Trade examinations, who have not had the advantage of the "Conway" preliminary training.		
The Practice of Navigation and Nautical Astronomy, complete with tables, by *Lieut. Raper, R.N.* ... ... (*See also* the "New" Navigation)	30	0
Nautical Tables, by *Lieut. Raper, R.N.* ... ... (do., do.)	21	0
In the 21st edition of this renowned work, published during the year 1920, various Tables have been added, to bring the work up to the standard of modern requirements.		
Inman's Nautical Tables. A New Edition of this standard work, revised and brought thoroughly up to the present date, and containing all the aids to rapid fixing of position which are essential in modern Navigation	21	0
Lectures on Elementary Navigation, by *Rev. J. B. Harbord, M.A. (Retired Naval Instructor, R.N.; late Inspector of Naval Schools, Admiralty; Examiner in Navigation and Nautical Astronomy for the Department of Science and Art; Author of "Glossary of Navigation")*	7	6
Navigation Simplified, by a System of Teaching based on First Principles, for Officers (from 2nd Mate to Extra Master) in the Mercantile Marine and Yachtsmen. Illustrated by numerous diagrams, by *Captain P. Thompson, F.R.A.S., Younger Brother of the Trinity House, Senior Examiner of Masters and Mates, and Secretary to the Local Marine Board of London*	12	0
Examination Diagrams Simplified, for Navigation Students; illustrated by sixteen diagrams (including 5½ inch Boxwood Scale), by *Captain P. Thompson, F.R.A.S.*	2	6
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Practical Coastal Navigation, with numerous charts and diagrams, by *Count de Miremont. 2nd Edition*	4	0
The book is a reprint of a series of papers brought out in the YACHTING AND BOATING MONTHLY MAGAZINE, and is specially intended to meet the requirements of yachtsmen, ambitious to navigate their own vessels. Including as it does the Longitude by Chronometer, the Time Azimuth solved by Tables, etc., with many useful hints on Navigation in Fog, and other matters, it has appealed to a wider circle of readers.		
Errors of the Four Point Bearing—and other Fixes dependent upon two Bearings of a single Object with the Run of Ship between them, and the Remedy (Several Diagrams), by *Capt. R. E. Carey*	3	0
This little work has a double object (1) to draw the attention of mariners to the danger attending the use of the Four Point Bearing method without making due allowance for current, and (2) to explain the details of an invention of the author designed to facilitate the application of the necessary correction.		

List of Nautical Works published by J. D. POTTER.

Tables of Allowance for Current when affecting Compass Course and Ship's Speed, by *Capt. G. E. Hoar, War Department Fleet.* A small and convenient Table to give by inspection the correction to a Compass Course made necessary by a Current in any direction, and the resulting distance made good. A desirable book for all Coastwise Navigation ... ... s. 2 d. 0

Every prudent navigator, in determining the course to be steered to make a given point, will naturally take into account the effect of any known current, but the allowance made in general is a matter of guess work. Captain Hoar's little work enables the correction to be made with precision. For each knot of ship's speed, from 3 to 30 knots, for each half knot of rate of current up to 8 knots, and for each 10° of angular direction between set of current and course to be made good, the Tables furnish to the decimal of a degree the allowance to be made. A supplementary column gives the distance made good per hour.

The "Hydra" Course Calculator. This diagram provides a quick and handy means of finding the allowance which must be made for the set of the current in order to find the course to steer to reach any desired position; in the case of aircraft the similar allowance which must be made for the drift due to the wind, can also be found. Price (with 12 pp. Booklet) 3 0

The "Hydra" Calculator is similar in its general object to Capt. Hoar's Tables, but is specially adapted also to solve various problems of the same nature as the current problems, that arise in Air Navigation.

"THE 'NEW' NAVIGATION."

Appendix to Raper's Practice of Navigation. Being an explanation of the New Astronomical Navigation by the method of Calculated Zenith Distances, with Special Tables for Simplifying and Shortening the work, by *William Hall, R.N., F.R.A.S., Chaplain and Naval Instructor (Chief Naval Instructor, Royal Australian Navy)* 2 6

A special feature of Mr. Hall's work is the Table of combined Natural and Logarithmic Versines. By means of combined Tables of this nature a great saving of labour is effected in various problems of Navigation. A further saving is obtained by giving values to four places of decimals only. It is gradually coming to be recognized that this number of places offers a degree of accuracy quite sufficient for all ordinary purposes.

NAUTICAL ASTRONOMY.

Nautical Astronomy, by *W. P. Symonds (Ex.-Commissioner of Surveys).* The best methods of calculating Hour-Angle, and finding Longitude and Latitude. The shortest Ex-Meridian method with New Table. Sidereal and Mean Time made clear. The New Navigation explained and the Modern methods of working Double Altitudes, and drawing Position lines. The Equation of Equal Altitudes made easy, and used for finding Longitude from Ex-Meridians, and for determining error in Latitude due to Ship moving N. or S. Lunars simplified. Chapters on finding Distances, the Tides, &c., with many diagrams 6 0

Nautical Astronomy Made Easy, by *A. C. Johnson, R.N.* All the Rules being worked by a Small Table on One Page, designed to economise Time and Labour ... 3 0

An Introduction to the Practice of Navigation and Nautical Astronomy, by *R. E. Hooppell, M.A., F.R.A.S.* 3 6

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